Paleoenvironmental Archives as a source of Climate Information for Natural Resource Management:

An Example from Tree Rings and Colorado Water Management

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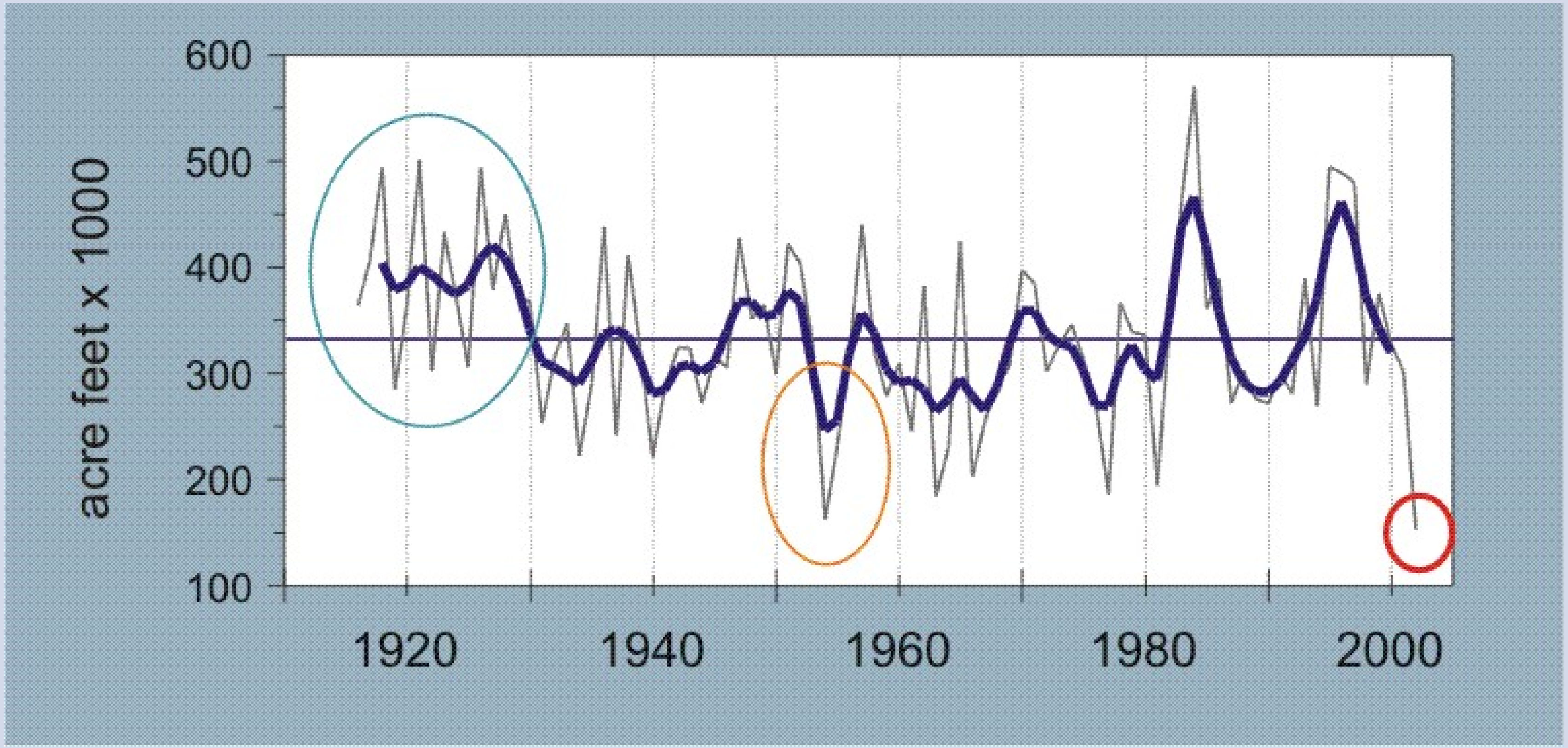
Why look into the past?

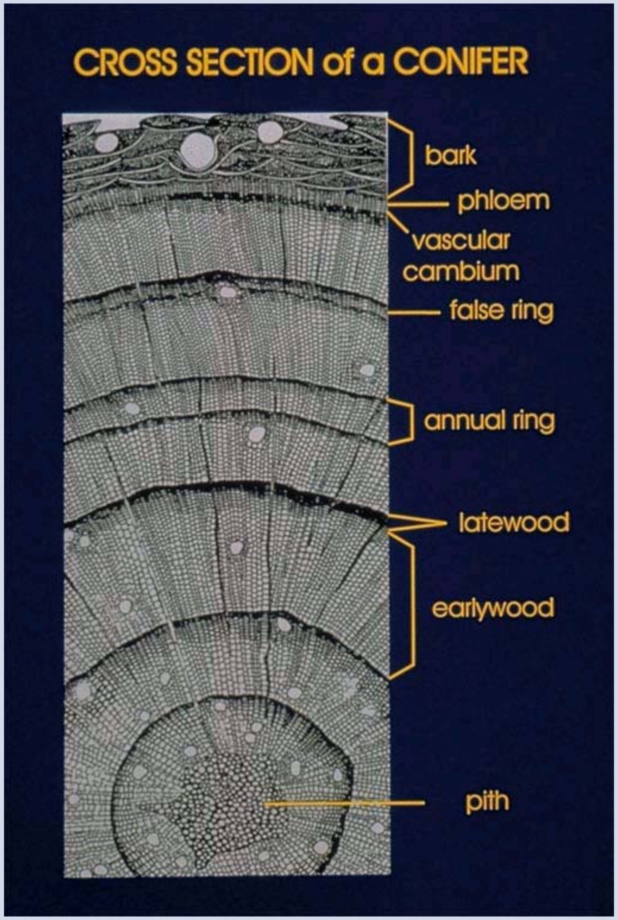
Colorado Headwaters (Fraser, Blue, William's Fork)
Annual Steamflow, 1916-2002



The 1950s drought has often been used in planning as a 'worst-case scenario,' while many water allocation agreements, such as the Colorado River compact, were based on the early part of the gage record, which was a relatively wet period. How representative are these events and periods over past centuries?

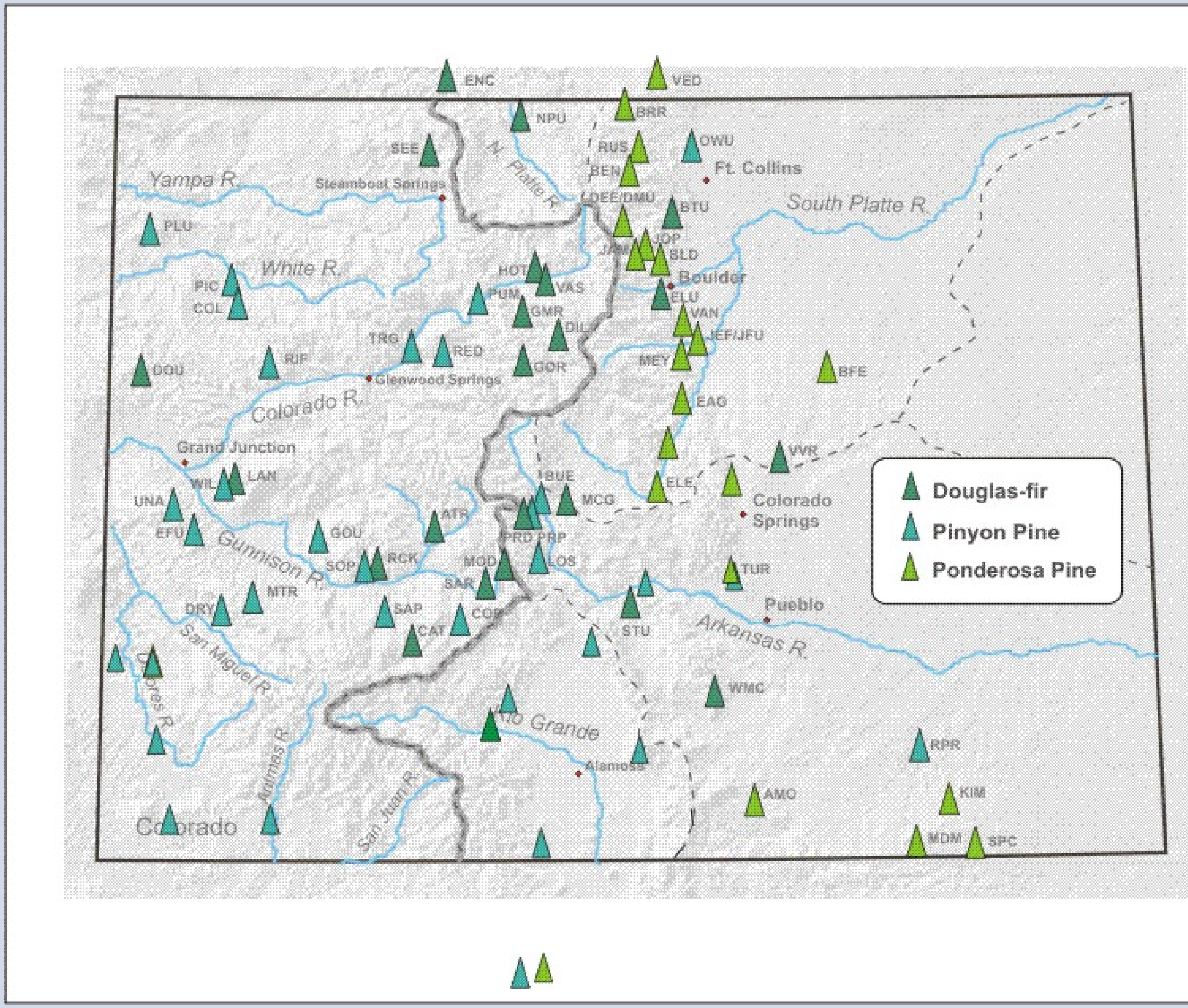
How is Past Streamflow Reconstructed from Tree Rings?

Cores collected from about 20 trees are dated, measured, and averaged into site tree-ring chronologies.

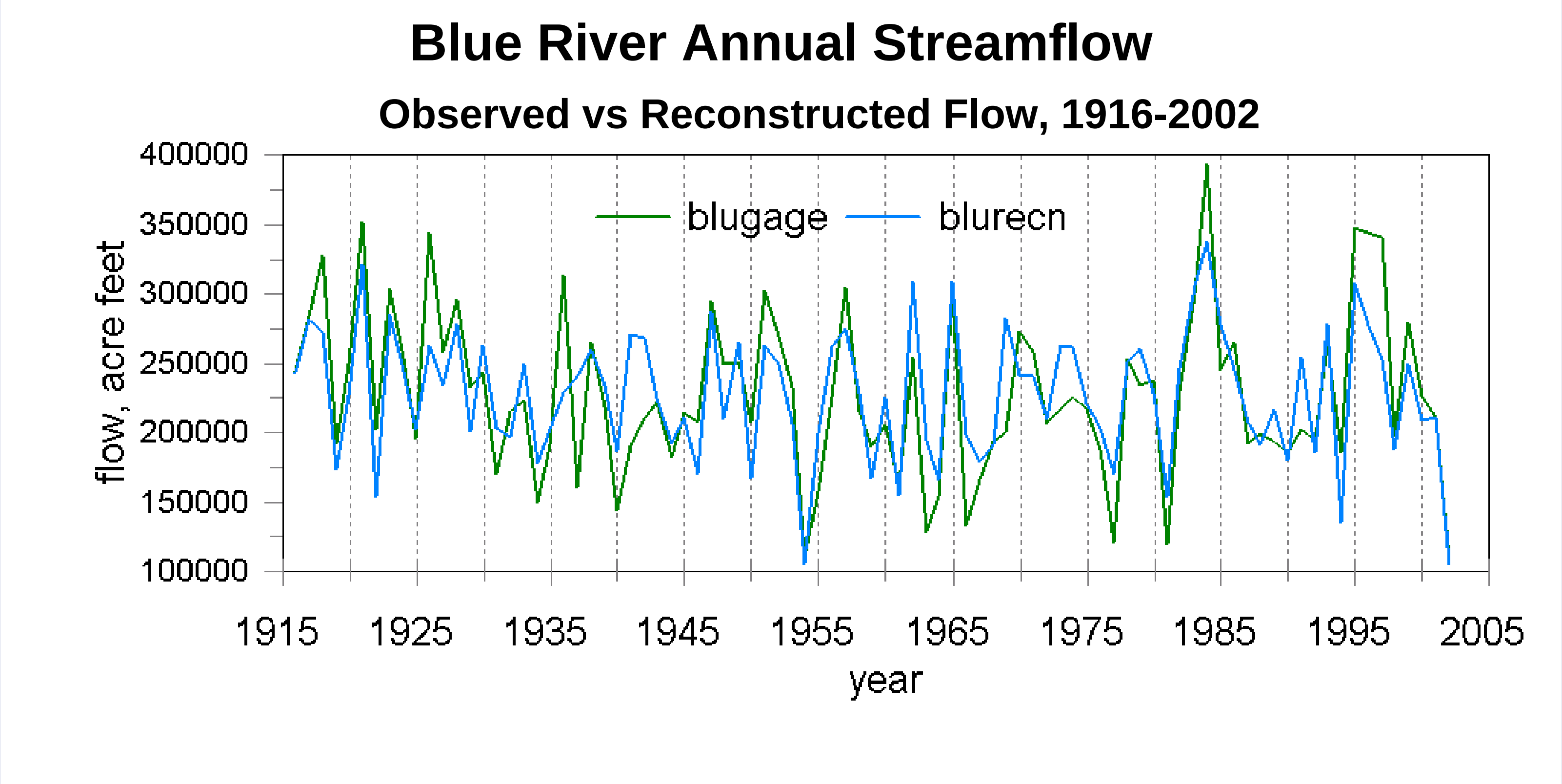


Moisture-sensitive tree species growing on open, well drained sites reflect hydroclimatic variability in their ring widths and targeted for collection.

Colorado tree-ring collections from moisture-sensitive sites



Tree-ring data are calibrated with annual steamflow to generate a statistical model of reconstructed flow

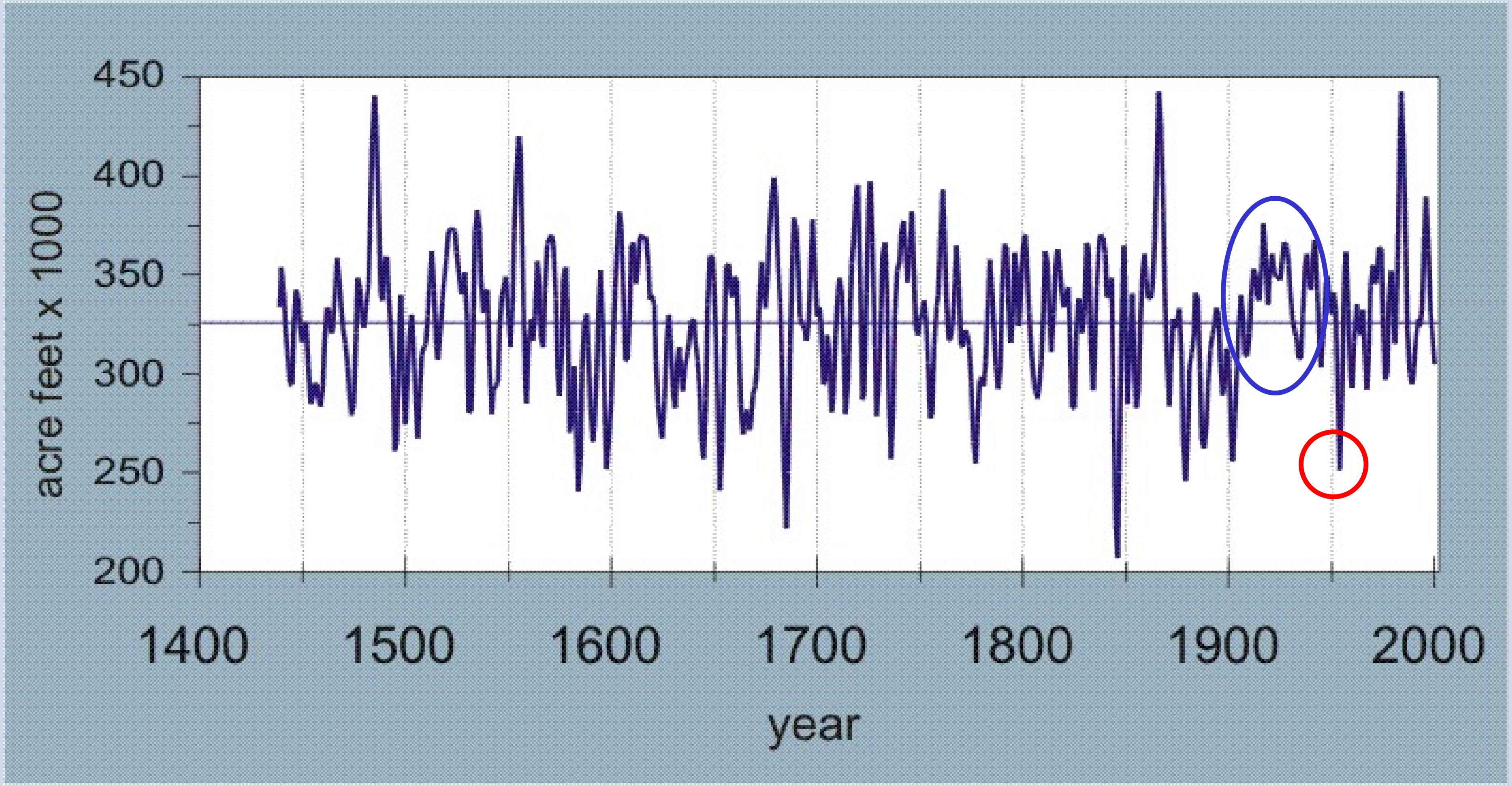


63% of the variance in the gage record is explained by the reconstruction.

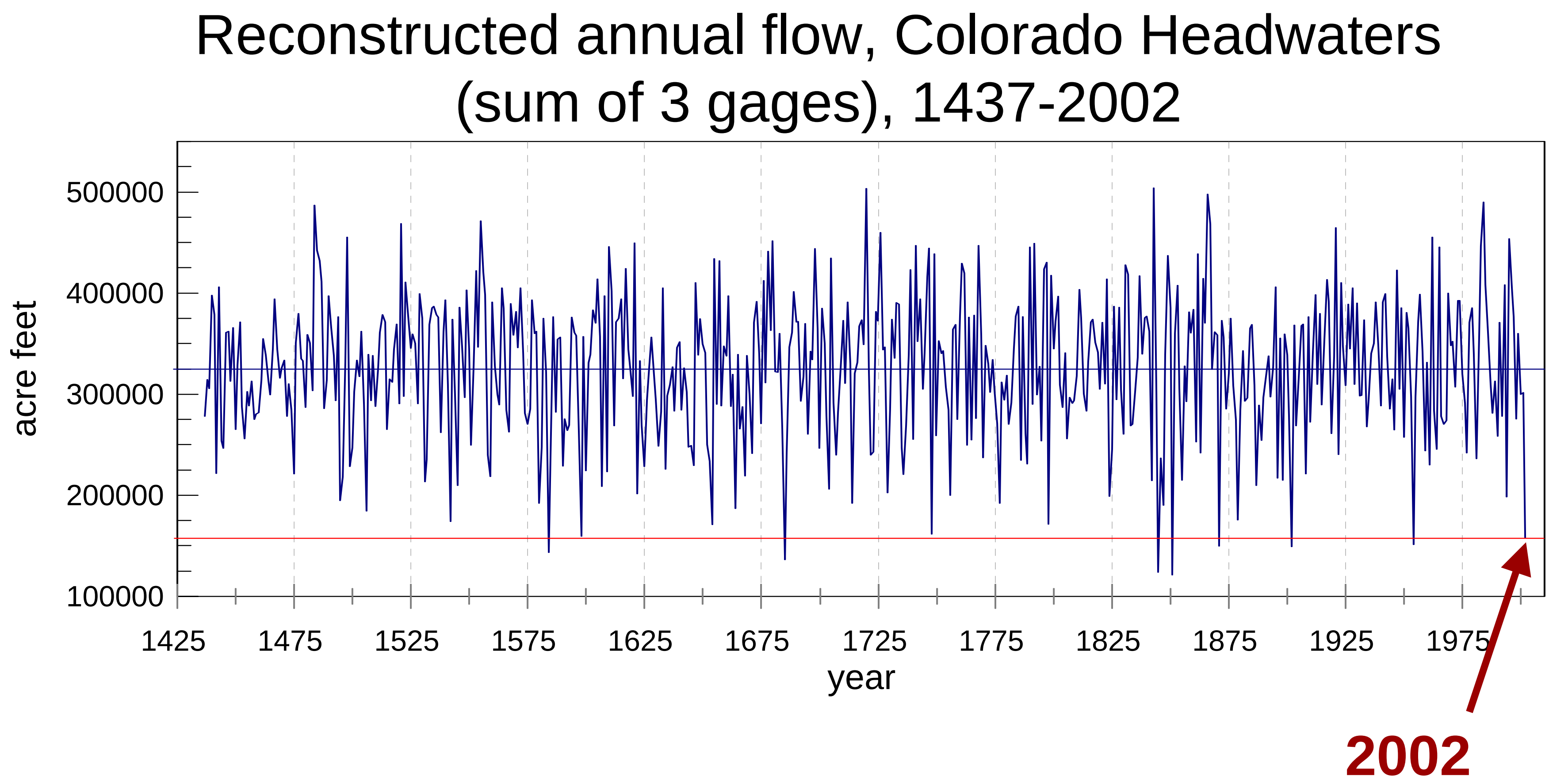
The unexplained variance is often in the magnitude of the extremes.

Reconstructed Colorado Headwaters Streamflow, 1437-2002

smoothed with a 5-weight filter

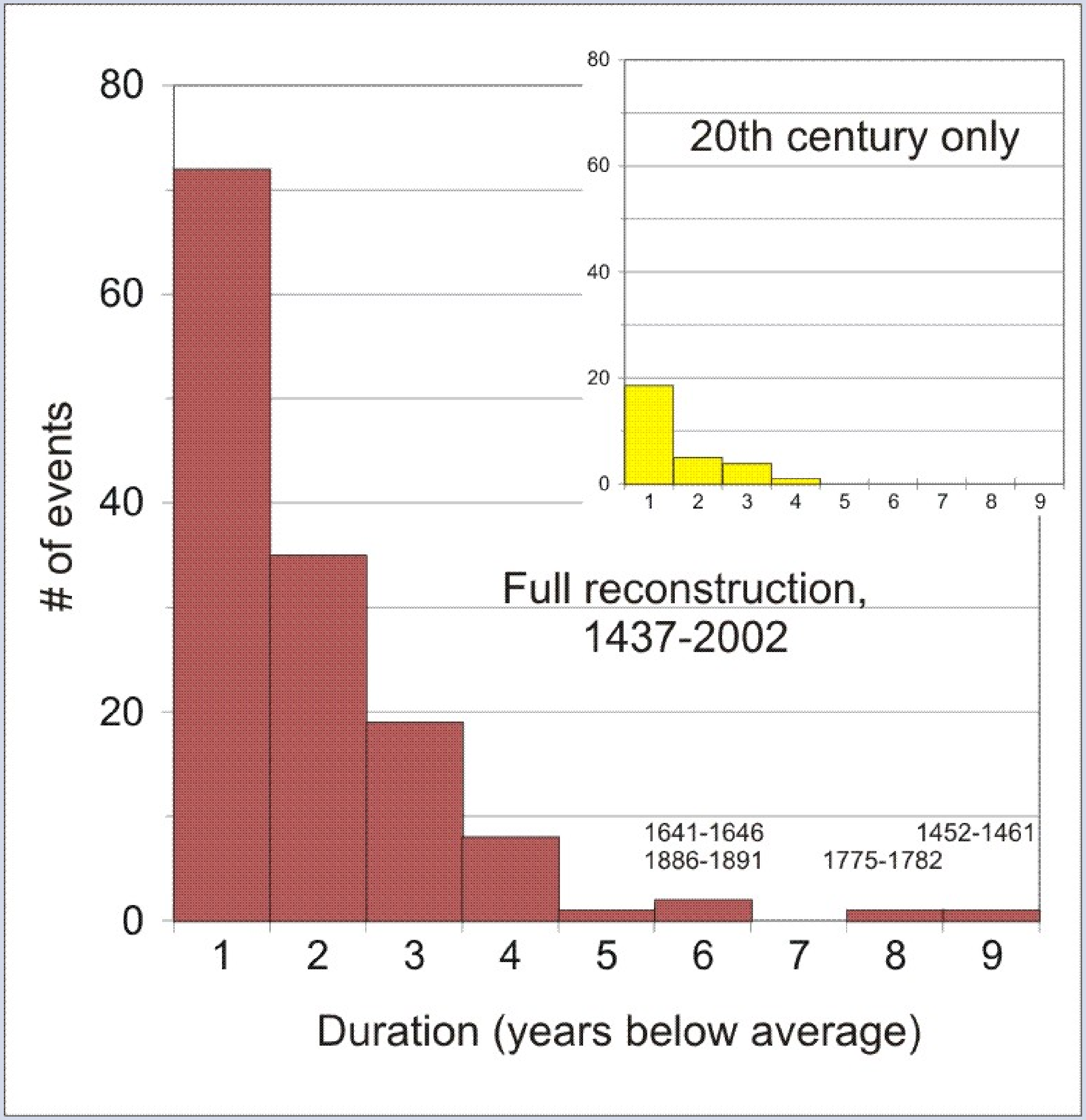


The early 20th century wet period does not appear matched in prior centuries. However, drought similar to the 1950s drought have occurred.



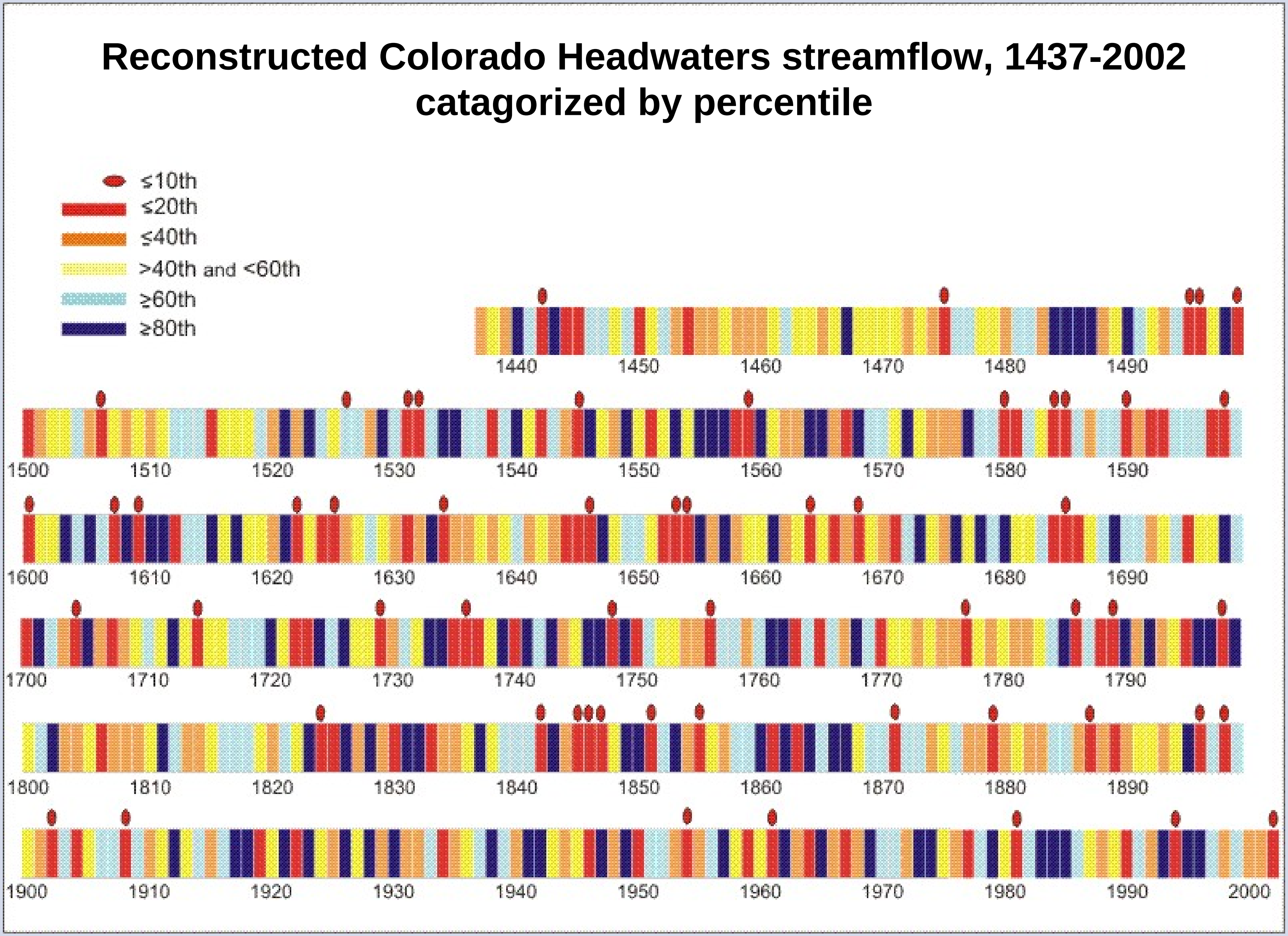
Water year flows in 2002 were the lowest on record in many Colorado gages, but how rare in the context of the past five centuries?

Reconstructed Colorado Headwaters Streamflow Drought Frequency



Here, drought is defined as one or more consecutive years below the long-term average.

Extreme events are not evenly distributed over time



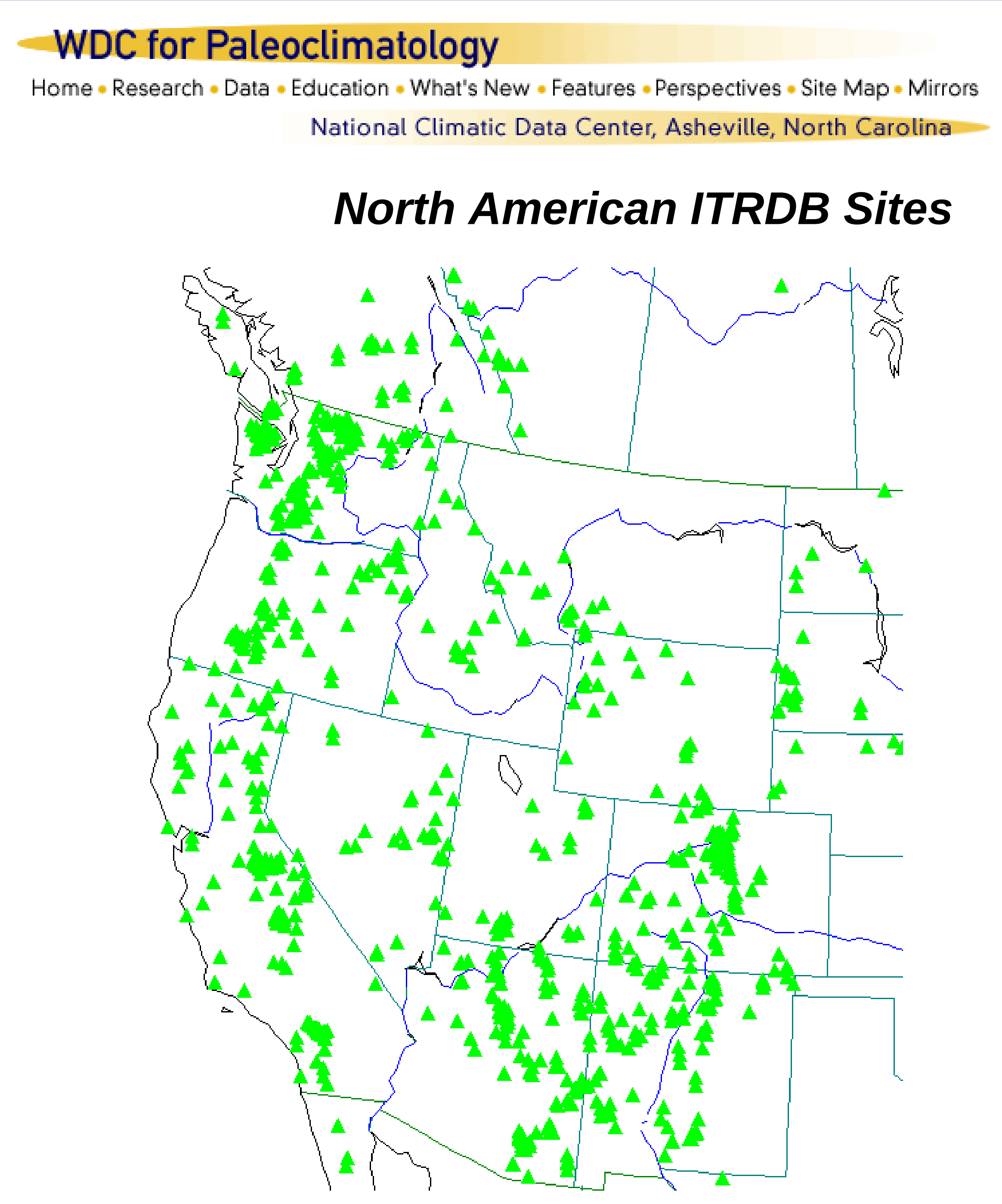
How are streamflow reconstructions being used by water providers and other decision makers?

- As input into models to determine whether a certain level of demand could be met in all years of the reconstruction, and what level of demand could be met during various sequences of drought years (Denver Water)
- To evaluate past droughts in comparison to 1950s (Denver Water)
- For scenarios using sequences of flow from reconstructions to evaluate the results of management decisions (e.g., setting of quotas) (Northern Colorado Water Conservancy District)
- As input into a network allocation model that allows difference water resources scenarios and futures (changes in use, demand, storage, management) (Northern and CU/SPRAT)
- For information on long-term low-variations in water supply (RGWCD)
- As part of the basis for legal decisions regarding well permits, compact negotiations?

What tree-ring data are available for other parts of the western U.S.?

The International Tree-Ring Data Bank (ITRDB)

http://www.ncdc.noaa.gov/paleo/treering.html



What climate reconstructions are available for other parts of the western U.S.?

WDC for Paleoclimatology

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National Climatic Data Center, Asheville, North Carolina

Climate Reconstructions

http://www.ncdc.noaa.gov/paleo/recons.html

DROUGHT

- NOAA/NESDIS North American Drought Variability (Tree-ring reconstructed PDSI).
- U.S. Drought Area Index, 270 Years, Cook et al. 1997.
- Southwest US Drought Index, 570 Years, Cook unpublished data.
- Eastern Colorado PDSI, 440 Years, Woodhouse et al. 2001.
- Texas PDSI, 280 Years, Stahle and Cleaveland 1988.
- Northeastern Utah PDSI, 600 Years, Gray et al. 2003.
- N. California and Nevada Multicentennial Droughts, 7600 Years, Benson et al. 2002.
- Upper Mississippi Basin Aridity, 10,000 Years, Dean et al. 1997.

PRECIPITATION

- Eastern Oregon Precipitation and PDSI, 300 Years, Garfin and Hughes 1997.
- Arizona and New Mexico Climate Division Precipitation, 1000 Years, Ni et al. 2002.
- El Malpais, New Mexico Precipitation, 2129 Years, Grissino 1996.
- Nevada Precipitation, 8000 Years, Hughes and Graumlich 1996.

STREAMFLOW

- Colorado River and tributaries flow reconstructions, Stockton and Jacoby 1976.
- Sacramento River, California flow reconstruction, 1109 Years, Meko et al. 2001.
- Yellowstone River, Montana flow reconstruction, 270 Years, Graumlich et al. 2003.
- TreeFlow Project - Tree Ring Reconstructions of Streamflow for Colorado
- Clear Creek Colorado Annual Flow Reconstruction, 300 Years, Woodhouse 2000.
- Middle Boulder Creek Colorado Flow Reconstruction, 280 Years, Woodhouse 2001.

Upper Yellowstone River Flow and Teleconnections with Pacific Basin Climate Variability during the Past Three Centuries

Upper Yellowstone River Flow and Teleconnections with Pacific Basin Climate Variability during the Past Three Centuries.

Climatic Change
July 2003, Volume 59, Issue 1-2, pp.245-262.

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ABSTRACT:
Climate variability, coupled with increasing demand is raising concerns about the sustainability of water resources in the western United States. Tree-ring reconstructions of stream flow that extend the observational record by several centuries provide critical information on the short-term variability and multi-decadal trends in water resources. In this study, precipitation sensitive Douglas-fir (Pseudotsuga menzeisii) tree ring records are used to reconstruct annual flow of the Yellowstone River back to A.D. 1706. Linkages between precipitation in the Greater Yellowstone Region and climate variability in the Pacific basin were incorporated into our model by including indices Pacific Ocean interannual and decadal-scale climatic variability, namely the Pacific Decadal Oscillation and the Southern Oscillation. The reconstruction indicates that 20th century streamflow is not representative of flow during the previous two centuries. With the exception of the 1930s, streamflow during the 20th century exceeded average flows during the previous 200 years. The drought of the 1930s resulted in the lowest flows during the last three centuries, however, this probably does not represent a worst-case scenario for the Yellowstone as other climate reconstructions indicate more extreme droughts prior to the 18th century.

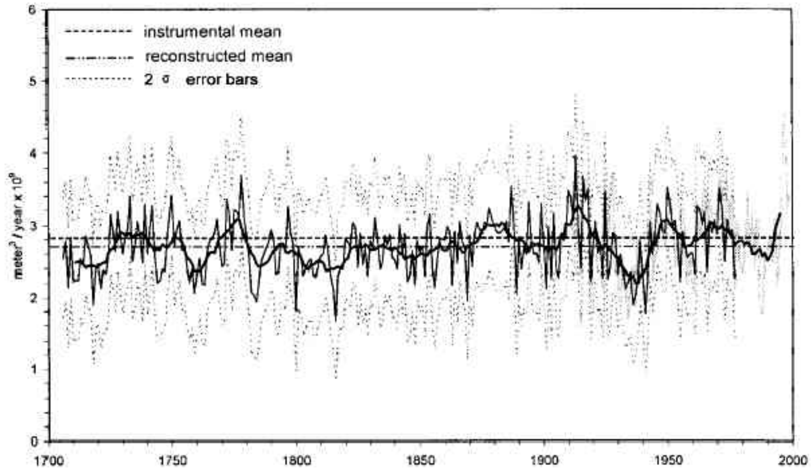
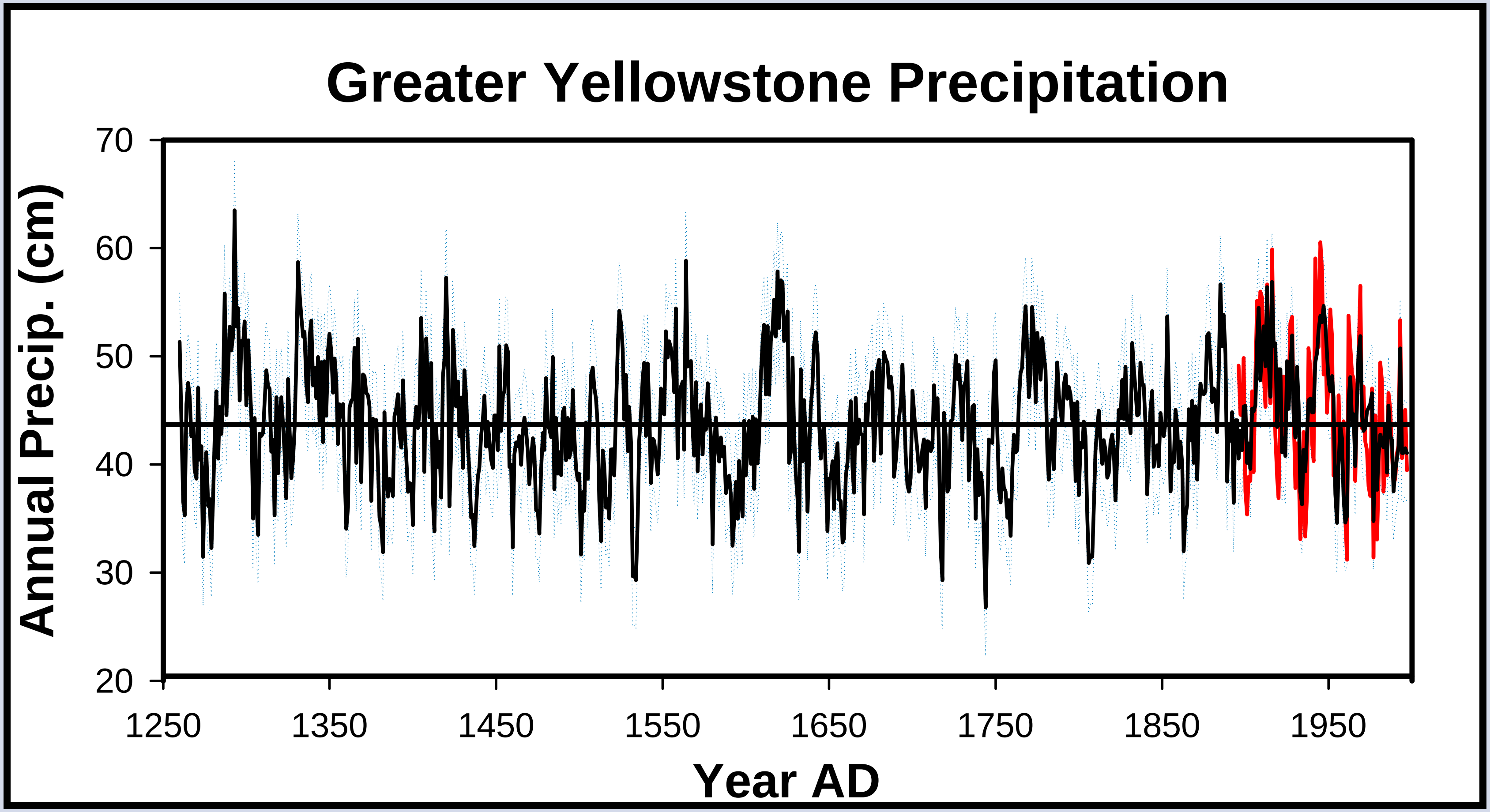


Fig. 5. Reconstruction of annual volume of flow for the Yellowstone River (1706-1977). Reconstructed flow (thin black line), actual flow (solid gray line), a 10-year moving average (thick black line) and 2 standard error confidence intervals (dashed gray lines) are shown.

DATA:
Download the reconstructed Upper Yellowstone River flow reconstruction from the WDC Paleo Archive.

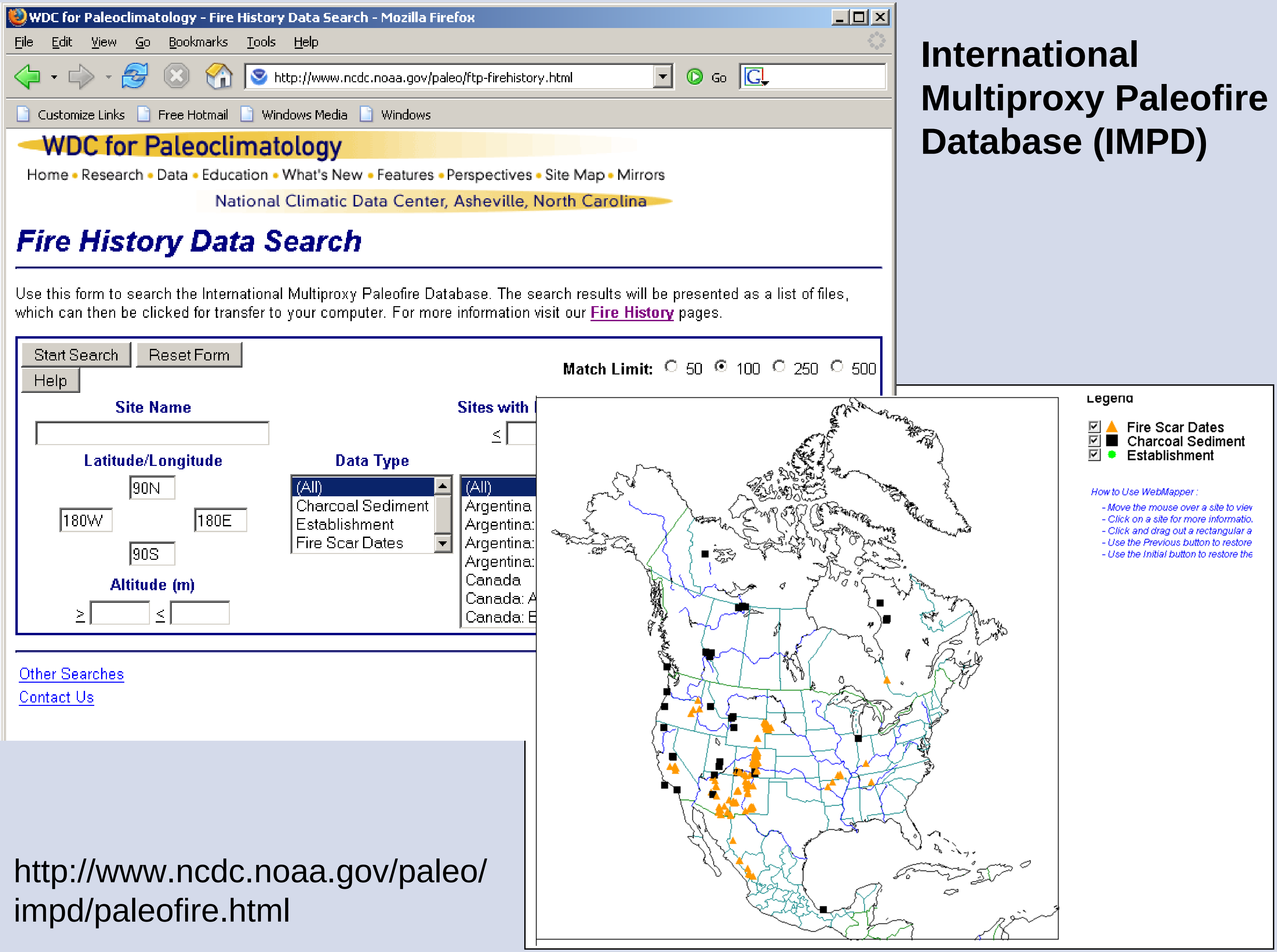
Download **Yellowstone River basin Douglas-fir (Pseudotsuga menziesii) data** used in this study from the International Tree Ring Data Bank.



- High variance explained ($r^2 = 0.58$)
- Well replicated (*n* = 133)
- Long segments (Avg. Length = 385 yr)
- Conservative detrending

Gray, Graumlich and Pisaric (in prep.)

International Multiproxy Paleofire Database (IMPD)



http://www.ncdc.noaa.gov/paleo/impd/paleofire.html

POSSIBLE DISCUSSION QUESTIONS

- What land management issues might be addressed with long-term records of natural variability from paleoclimatic data?

- What measurement metrics are important for monitoring long-term variability, and are proxy data appropriate and/or available for this purpose?

- What are data needs (e.g., specific locations) and/or requirements (e.g., spatial and temporal resolution) for using paleoclimatic data in land management?